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Supernovae in isolated galaxies, in pairs and in groups of galaxies

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ABSTRACT

In order to investigate the influence of the environment on the supernova (SN) production we have performed a statistical investigation of the SNe discovered in isolated galaxies, in pairs and in groups of galaxies. 22 SNe in 18 isolated galaxies, 48 SNe in 40 galaxies members of 37 pairs and 211 SNe in 170 galaxies members of 116 groups have been selected and studied.

We found that the radial distributions of core-collapse SNe in galaxies located in different environments are similar, and consistent with that reported by Bartunov, Makarova & Tsvetkov (1992). SNe discovered in pairs do not privilege a particular direction with respect to the companion galaxy. Also the azimuthal distributions inside the hosts members of galaxy groups are consistent with being isotropics. The fact that SNe are more frequent in the brighter components of the pairs and groups is expected from the dependence of the SN rates on the galaxy luminosity.

There is an indication that the SN rate is higher in galaxy pairs compared with that in groups. This can be related to the enhanced star formation rate in strongly interacting systems.

It is concluded that, with the possible exception of strongly interacting system, the parent galaxy environment has no direct influence on the SN production

Key words: Stars: formation, supernovae: general, Galaxies: interactions, stellar content

1 INTRODUCTION

The stellar content and the history of the star formation (SF) are the key parameters determining the evolution of galaxies. In this respect the determination of the star formation rates (SFRs) in the galaxies is a first step toward the characterization of different systems.

Among the various methods conceived to estimate the SFRs in galaxies the most widely used are based on the integrated colors, the emission lines, the UV and FIR luminosities (e.g. Kennicutt 1998).

It is often claimed that different factors enhance the star formation in galaxies above the average value for the given morphological type. In particular, several authors have proposed gravitational interaction as a possible SF triggering mechanism. Evidences in this respect come from statistical studies showing that the fraction of interacting galaxies is higher than average in Markarian objects (e.g. Heidmann & Kalloghlian 1973, Keel & van Soest 1992). Further the peculiar colors of interacting systems are attributed to the occurrence of bursts of star formation (e.g. Larson & Tinsley 1978, Kennicutt et al. 1987). Finally, *IRAS* observations have shown that interacting systems emit a higher infrared luminosity than isolated ones which can be combined with the knowledge that very luminous infrared galaxies have experienced strong nuclear starburst (e.g., Soifer et al. 1984, Sanders et al. 1988, Melnick & Mirabel 1990, Wu et al. 1998). Detailed investigations of the relation between interaction and star formation show that most of star formation takes place in the central regions of the galaxies (e.g. Hodge 1975, Arp 1973, Laurikainen & Moles 1989, Petrosian & Turatto 1995, Laurikainen, Salo & Aparicio 1998) and in the tidal streams (e.g. Schombert, Wallin & Struck-Marcell 1990, Thronson et al. 1989). Whether SF is stimulated also in less dense environments such as compact groups of galaxies is still questioned. For instance, Moles et al. (1994) find a slight enhancement of SF in the galaxies members of com-

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pact groups, while Iglesias-Paramo & Vilchez (1999) do not confirm such finding.

It is now widely accepted that most SNe can be assigned to two main physical classes, core collapse (type II and Ib/c SNe) and thermonuclear explosions (type Ia SNe).

The rates per unit blue luminosity of type Ia SNe, were found to increase (Oemler & Tinsley 1979, Cappellaro et al. 1993b, 1997) or at least to remain constant (Cappellaro, Evans & Turatto 1999) moving from early to late type galaxies. Because in late spirals there is a significant contribution to the blue luminosity by young stellar population this immediately implies that the average age of SNIa progenitors in spirals is shorter than in ellipticals.

Kochhar (1989, 1990) has suggested that all SNIa are short-lived stars, hence that early type SN host galaxies have on-going star formation. However, Turatto, Cappellaro & Benetti (1994) showing that the rate of SNIa in ellipticals does not depend on the gas or dust content, did not confirm this conclusion.

Type II SNe originate from young massive stars associated to the ongoing process of star formation (e.g. Branch et al. 1991) and this is why they appear concentrated in star forming sites (e.g. Maza & van den Bergh 1976, Bartunov, Tsvetkov & Filimonova 1994, Van Dyk 1992, Van Dyk , Hamuy & Filippenko 1996, Van Dyk et al. 1999). The discovery of intermediate cases (e.g. SN 1993J) sharing the properties of SNII at early time and those of SNIb in the nebular phase is the observational proof that also SNIb/c are also related to massive progenitors.

Cappellaro et al. (1999) have shown that the rate of core-collapse SNe is related to the FIR excess and to the color of galaxies, justifying the use of the rate of core collapse SNe as SF indicators.

Following the approach of Turatto, Cappellaro & Petrosian (1989) and Petrosian & Turatto (1990, 1992, 1995), in this paper we will use the rates and the locations of SNII and Ib/c in order to study the relation between the star formation in galaxies and the galaxy environment, in selected samples of isolated galaxies, pairs of galaxies and groups. The same study is performed also for Ia type SNe.

The samples of SNe in isolated galaxies as well as in members of pairs and groups of galaxies are presented in Section 2. The rates, radial and azimuthal distributions in the parent systems along with the results of the Multivariate Factor Analysis are analyzed and discussed in Section 3. Conclusions are drown in Section 4.

Through this article we have assumed for the Hubble constant a value of $H_0 = 75$ km s^{-1}Mpc^{-1}.

2 THE SAMPLES

The selection of the samples has been done by crossing a working version (updated to mid 1998) of the Asiago Supernova Catalogue (Barbon et al. 1984, 1989, 1999, hereafter ASC) with:

(i) the catalogue of Isolated Galaxies (Karachentseva 1973, hereafter KIG),

(ii) the Catalogues of isolated pairs of galaxies in the northern and southern hemispheres (Karachentsev 1972, Reduzzi & Rampazzo 1995 hereafter KPG , RRPG respectively)

(iii) the Catalogue of Nearby Groups of Galaxies (Garcia 1993, hereafter LGG).

It turns out that 22 SNe have been discovered in 18 isolated galaxies. Table 1 summarizes the main data for these SNe and their parent galaxies. In the first column is the galaxy running number according to KIG and in column 2 is the most common identification for the galaxy. In column 3 and 4, respectively, is the morphological type and the activity class as reported in NED. When for the same object alternative activity classifications are given in the literature (Seyfert (Sy) or Liner (L)) we preferred the Sy classification. Column 5 reports the absolute blue magnitude (M_B) of SN host galaxy from the Lyon-Meudon Extragalactic Database (LEDA). Logarithmic ratios of the FIR to B luminosities of SNe host galaxies ($\log(L_{FIR}/L_B)$) are listed in column 6 where the FIR luminosity was computed according to Lonsdale et al. (1985). SN designations and classifications from ASC are presented in columns 7 and 8, respectively. The relative distance of the SN from the center of parent galaxy corrected for the tilting of the galaxy along the line of sight (R_0/R_{25}, McCarthy 1973) is in column 9. The last column 10 reports individual notes. It is worth noting that because of the different criteria used, two galaxies of the isolated sample belong also to the groups as defined by Garcia (1993).

In isolated galaxies out of 22 SNe, 14 are type II+Ib/c, 4 are type Ia and 4 are unclassified. 55% of the SNe discovered in spirals have barred hosts. 18% of hosts have Sy nuclei which become 22% if we include also Liners.

Table 2 lists the 48 SNe discovered in 40 galaxies members of 37 pairs of galaxies. The first six columns of Table 2 contain the same information as in Table 1 while Column 7 lists the logarithmic ratio of the blue luminosity of the SN host galaxy to that of its neighbor. Velocity differences of the members of the pairs are given in Column 8. In order to take only physical systems we have excluded all pairs for which the velocity difference between the components is higher than 500 km s^{-1} or is unknown. Columns 9, 10 and 11 of Table 2 respectively are the same with Columns of 7, 8, 9 of Table 1. In addition, Column 12 lists the ratio of the projected distance of SN from the center of its host galaxy to the projected distance of the pair members. Column 13 reports the position angle (PA) of the SNe with respect to the line connecting the center of the parent galaxy to its neighbor. The PAs are calculated clockwise with the neighbor placed at 180°. Notes are presented in Column 14 .

In pairs of galaxies out of the 48 SNe 9 are type Ia, 19 are type II+Ib/c and the remaining are either type I or unclassified. A bar is present in the 65% of the spiral parent galaxies. In this sample, 8% of the SNe occurs in active nuclei hosts (19% with Liners). SNe are discovered more frequently in the luminous component of the pairs (72 % of cases) than in the fainter one.

Finally, we have identified SNe discovered in groups of galaxies. The group definition was taken according to the "hard criterion", i.e. Huchra-Geller percolation, Tully hierarchical and 2D wavelet methods (Garcia 1993). The crossing produced a list of 211 SNe discovered in 170 galaxies members of 116 groups (Table 3). In Table 3 Columns 1, 2 and 3 report Garcia's designations, group member counts and mean morphological class (MMC) of groups. The MMC was calculated as MMC $= \sum X_i/N$, where N is the num-

Table 1. Known SN hosts among isolated galaxies.

Name of (1)	Galaxy (2)	Type (3)	AGN (4)	M_B (5)	$\mathrm{Log}(L_{FIR}/L_B)$ (6)	SN (7)	(8)	R_0/R_{25} (9)	Notes (10)
KIG15	CGCG 479- 4	Sc		-21.58		1954 F		0.52	
KIG104	UGC 1903	SBb		-21.31		1964 N		0.70	
KIG138	UGC 2936	SBd		-20.33	0.04	1991 bd	Ia	0.50	
KIG197	NGC 2403	SABcd		-19.57	-1.35	1954 J	V	0.27	
KIG309	NGC 2775	Sab		-20.56	-1.16	1993 Z	Ia	0.40	LGG169(2)
KIG324	NGC 2841	Sb	Sy1	-20.83	-1.59	1912 A		0.34	
KIG324	NGC 2841	Sb	Sy1	-20.83	-1.59	1957 A	Ia	0.69	
KIG324	NGC 2841	Sb	Sy1	-20.83	-1.59	1972 R	Ib	0.78	
KIG358	NGC 2954	E		-20.53		1993 C	Ia	0.99	
KIG442	NGC 3359	SBc		-20.75	-1.23	1985 H	II	0.24	
KIG464	NGC 3526	Sc		-19.02	-1.05	1995 H	II	0.54	
KIG469	NGC 3556	SBcd		-20.99	-0.95	1969 B	II	0.32	
KIG549	NGC 4651	Sc	L	-19.53	-0.88	1987 K	IIb	0.20	
KIG605	NGC 5375	SBab		-20.25	-1.27	1989 K	II	0.79	
KIG604	NGC 5377	SBa		-20.25	-1.17	1992 H	II	0.56	
KIG610	NGC 5457	SABcd		-20.87	-0.55	1909 A	II	0.86	LGG371(1)
KIG610	NGC 5457	SABcd		-20.87	-0.55	1951 H	II	0.41	LGG371(1)
KIG610	NGC 5457	SABcd		-20.87	-0.55	1970 G	II	0.45	LGG371(1)
KIG772	IC 1231	Scd		-21.47	-1.39	1976 C?		0.80	
KIG812	NGC 6389	Sbc		-21.22	-0.91	1992 ab	II	1.10	
KIG967	NGC 7292	IBm		-18.61	-1.04	1964 H	II	0.46	
KIG1004	NGC 7479	SBc	Sy2	-21.40	-0.40	1990 U	Ic	0.46	

Table 2. Known SN hosts among pair member galaxies.

Name of (1)	Galaxy (2)	Type (3)	AGN (4)	M_B (5)	Log $(\frac{L_{FIR}}{L_B})$ (6)	Log $(\frac{L_P}{L_N})$ (7)	$\triangle V$ (8)	SN (9)	(10)	$\frac{R_0}{R_{25}}$ (11)	$\frac{R_{SN}}{R_{1,2}}$ (12)	PA (13)	Notes (14)
KPG127A	NGC2276	SABc		-21.34	-0.36	0.18	409	1962 Q		0.44	0.09	43	
KPG127A	NGC2276	SABc		-21.34	-0.36	0.18	409	1968V	II	0.63	0.13	339	
KPG127A	NGC2276	SABc		-21.34	-0.36	0.18	409	1968W		0.12	0.03	340	
KPG127A	NGC2276	SABc		-21.34	-0.36	0.18	409	1993X	II	0.89	0.20	271	
KPG132A	NGC2336	SABbc		-22.31	-1.54	0.78	148	1987 L	Ia	0.62	0.08	202	
KPG150B	NGC2487	SBb		-21.32	-0.95	0.34	383	1975 O	Ia	0.44	0.09	136	LGG152(3)
KPG156A	NGC2535	Sc		-21.26	-0.58	0.55	63	1901 A		0.27	0.19	270	
KPG175A	NGC2672	E1-2		-21.40		0.65	406	1938 B		0.41	1.08	126	
KPG210B	NGC2968	I0		-19.20		-0.34	269	1970 L	I	2.05	0.38	339	
KPG218A	NGC3031	Sab	Sy1.8	-21.56	-2.56	1.20	349	1993 J	II b	0.29	0.08	346	LGG176(3)
KPG228B	NGC3169	Sa	L	-20.47	-0.77	0.03	65	1984 E	II L	0.68	0.14	146	LGG192(4)
KPG234A	NGC3226	E2	L	-19.25		-0.37	177	1976 K	I	0.37	0.25	284	LGG194(8)
KPG234B	NGC3227	SABc	Sy1.5	-20.18	-0.73	0.37	177	1983 U	Ia	0.16	0.15	249	LGG194(9)
KPG281A	NGC3646	Ring		-22.72		1.10	181	1989 N	II	0.51	0.11	42	
KPG282A	NGC3656	I		-19.97	-0.35	0.79	30	1973 C		0.45	1.18	110	
KPG282A	NGC3656	I		-19.97	-0.35	0.79	30	1963 K	I	0.26	0.67	212	
KPG288A	NGC3690	SBm?		-22.18	0.33	0.24	99	1990 al?		0.33	0.86	338	
KPG288A	NGC3690	SBm?		-22.18	0.33	0.24	99	1992bu?		0.12	0.26	284	
KPG288A	NGC3690	SBm?		-22.18	0.33	0.24	99	1993 G	II	0.31	0.66	219	
KPG332B	NGC4302	Sc		-20.02		0.14	11	1986 E	II	0.71	0.85	113	LGG289(6)
KPG334A	NGC4382	S0		-20.43		0.50	50	1960 R	Ia	0.63	0.28	84	LGG292(35)
KPG335B	NGC4410B	SABcd		-21.16		-0.14	30	1965 A	I	1.27	1.00	27	
KPG336B	NGC4411B	SABcd		-18.50	-1.09	0.16	22	1992 ad	II	0.58	0.17	303	LGG289(39)
KPG341B	NGC4490	SBd		-20.67	-0.81	1.04	23	1982 F	II	0.4	0.18	49	LGG290(8)
KPG345A	NGC4512	SBdm		-18.99	-1.00	-0.46	454	1995 J	II	0.79	0.17	150	LGG295(2)
KPG347B	NGC4568	Sbc		-21.61		0.30	47	1990 B	Ib/c	0.08	0.15	219	LGG285(24)
KPG348B	NGC4615	Scd		-21.10	-0.61	0.38	78	1987 F	IIn	0.52	0.15	291	
KPG349A	NGC4618	SBm		-19.04	-1.17	0.60	8	1985 F	Ib/c	0.06	0.03	143	LGG290(10)
KPG353A	NGC4647	SABc		-19.93	-0.56	-0.62	307	1979 A	I	0.68	0.38	14	LGG289(49)
KPG379A	NGC5194	Sbc	Sy2	-20.50	-0.52	0.24	107	1994 I	Ic	0.07	0.07	64	LGG347(4)
KPG379B	NGC5195	SB0	L	-19.90	-1.37	-0.24	107	1945 A	I	0.04	0.03	140	LGG347(8)
KPG411B	M+02-36-26	Sb		-21.58		-0.03	291	1951 B		0.52	0.45	200	LGG372(3)
KPG416A	NGC5480	Sc		-19.94	-0.51	0.20	232	1988 L	Ib	0.28	0.07	258	
KPG434B	NGC5746	SABb		-21.86	-1.50	0.828	183	1983 P	Ia	0.15	0.01	259	LGG386(5)
KPG455A	NGC5857	SBb		-20.96		-0.40	5	1950 H		0.75	0.20	148	LGG394(2)
KPG455A	NGC5857	SBb		-20.96		-0.40	5	1955 M		1.03	0.30	348	
KPG536A	NGC6636	Sc	Sy2	-20.77	-0.50	0.72	427	1989 P	Ia	1.16	1.90	29	
KPG570B	NGC7339	SABbc		-19.68		-0.10	54	1989 L	II n	0.44	0.12	317	
KPG68B	IC1801	SBb		-19.66		-0.57	189	1976 H?		0.49	0.26	317	LGG61(5)
KPG9B	M+02-02-09	S?		-19.97			97	1990 ah	II	0.28	0.19	59	
RRPG70B	NGC1187	SBc		-20.24	-0.37		45	1982 R	Ib	0.54	0.25	126	
RRPG75A	NGC1316	SAB0	L	-22.11	-1.50	0.77	155	1980 N	Ia	0.71	0.57	93	LGG94(2)
RRPG75A	NGC1316	SAB0	L	-22.11	-1.50	0.77	155	1981 D	Ia	0.34	0.26	351	
RRPG85A	NGC1532	SBb		-20.89	-1.26	0.52	436	1981 A	II	0.53	0.02	65	LGG111(3)
RRPG132A	NGC2207	SABbc		-21.63		-0.23	109	1975 A	Ia	0.98	0.95	229	
RRPG206B	NGC4039	Sm		-21.12		-0.10	9	1921 A		0.32	0.39	46	LGG263(9)
RRPG206A	NGC4038	SBm		-21.36		0.10	9	1974 E		0.65	1.03	219	LGG263(8)
RRPG242A	NGC5090	E2		-21.17		0.12	216	1981 C?		0.29	0.33	173	LGG339(8)

ber of galaxies in the groups and Xi is a code describing the morphological type of ith galaxy. Elliptical galaxies correspond to 1, S0 to 2, Spirals and Irregulars to 3 and 4, respectively. In Column 4 is the standard deviation of heliocentric radial velocities of group members expressed in km s^{-1}. Columns 5, 6, 7, 8 and 9 respectively are the same as Columns 2, 3, 4, 5 and 6 of Table 1. The logarithmic ratio of the blue luminosity of the SN host galaxy to that of the most luminous member of the group is in Column 10. Column 11 is the ratio of the distance of the SN host galaxy from the geometrical center of the group to the group radius. The latter computed as the distance of the most distant member from the geometrical center of the group. Columns 12, 13 and 14 are the same with Columns 7, 8 and 9 of Table 1. In Column 15 of Table 3 is the position angle (PA) of the SN with respect to the line connecting the geometrical center of group to the SN host. PA is calculated clockwise with the geometrical center placed at 180°. Column 16 are notes.

In this sample 65 SNe are classified as type Ia, 84 SNe as type II+Ib/c and 62 SNe are unclassified. 59% of SNe

are in spirals hosts with barred structure. 14% of SNe hosts have active nuclei (18 % if we include Liners). 36% of SNe occurred in the most luminous galaxies of the groups.

It is worth noting again that, because of different selection criteria, the KIG and KPG (+RRPG) samples have significant intersection with the Garcia's groups. In particular, about 50% of the isolated pairs are the seeds of larger LGG aggregations.

3 ANALYSIS AND DISCUSSION

3.1 The properties of the host galaxies

Table 4 presents the mean values and standard deviations of the absolute blue magnitudes ($< M_B >$) and morphological types ($< T >$) of SNe host galaxies for the different systems.

It appears that there are not significant differences (significance level of 95%) among the means of blue luminosity of host galaxies of core collapse SNe in different environments. Instead, the average absolute blue luminosity of parent galaxies of type Ia SNe in pairs is significantly higher (significant level p=0.01 or 99.1%) than in other systems. We could not find an obviuos explanation for this finding, though we should be wary of the small statisics. Indeed of the 9 SN Ia in paired galaxies, two were discovered in the giant galaxy NGC1316 ($M_B = 22.11$).

Not significant differences appear in the mean morphological types of parent galaxies of all types of SNe in different environments. As expected the morphological types of the hosts of core collapse SNe is more advanced than those of type Ia. Indeed, type II+Ib/c SNe occurs only in late type galaxies while SNIa occurs in all kind of galaxies (Barbon et al. 1999).

3.2 The location of the SNe inside the host systems

The small statistics in the samples of KIG and KPG+RRPG does not allow the comparison of the radial distributions between the two SNe types in pairs. Where we have sufficient statistics as in the case of the LGG, a two-sample Kolmogorov-Smirnov (K-S) test does not show any difference between SNe Ia and SNe II+Ib/c (significance level of 95%) in the distributions of the relative radial distances - R_0/R_{25}, corrected for the inclination along the line of sight (McCarthy 1973). A similar result was found by Bartunov et al. (1992) who showed that SNIa and SNII in a general sample of galaxies have similar gradients in the relative radial distributions and similar scale lengths.

We then compared the radial distributions of the core collapse SNe in the three samples defined in Sect. 2 with that of the reference sample of Bartunov et al. (1992) containing 121 objects (Figure 1). The two sample K-S test shows that all the distribution come from the same population indicating that the star forming regions in galaxies with different environments have the same radial distribution.

This result is at variance with the results by Petrosian & Turatto (1995) for the core collapse SNe in strongly interacting systems. A new computation with better statistics has shown that the radial distribution of the SNeII in strongly interacting systems resembles that of our KPG sample. We conclude that if the interaction triggers star formation in the central regions of the galaxies, this is too close to the nucleus to be detected by most current SN searches.

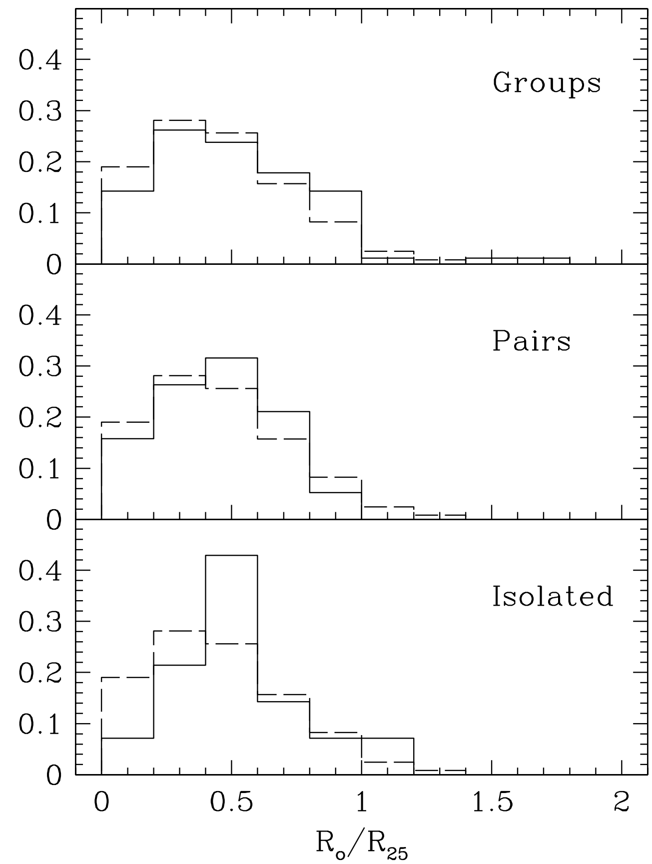

Figure 1. Histograms of the relative radial distributions of the SNe in isolated parent galaxies (KIG), pairs of galaxies (KPG+RRPG) and Garcia's groups. The relative radial distances have been corrected for the inclination along the line of view as McCarthy (1973). Long dashed line is the radial distribution in the reference sample of SNe from Bartunov et al. (1992).

The SNe azimuth distributions in the galaxy systems has been studied by measuring the SNe position angles relative to the companions. In galaxy pairs 23 SNe (45.1%) were located on the side of the host galaxy pointing to the companion (60% of SNe type Ia and 40% of type II+Ib/c). According to K-S tests the PA distributions of both types of SNe are not significantly different from the homogeneous one. Similar result was found in the closely interacting systems by Petrosian & Turatto (1995).

A similar test has been performed for the location of SNe in the host galaxies relative to the geometrical center of the groups. 54.7% of type Ia SNe and 50.6% of type II+Ib/c SNe occur on the side of the geometrical center of the groups. Again a K-S test show no preferential direction in the SN distribution. This means that star formation inside the parent galaxies of SNe is not affected by local mass concentration. This is not surprising since we found no influence in the case of interacting neighbors.

The radial distributions (R_0/R_{25}) of the SNe located on the side of the companion in galaxy pairs and on the side

Table 3. Known SN hosts in groups member galaxies

Cat.Name	N	MMC	Sigma	Name	Type	AGN	M_B	Log $\frac{L_{FIR}}{L_B}$	Log $\frac{L_P}{L_{LG}}$	$\frac{R_P}{R_{GR}}$	SN		$\frac{R_0}{R_{25}}$	PA	Notes
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
LGG 2	5	3.00	57	NGC 23	SBa		-21.73	-0.13	0	0.20	1955 C?		0.29	315	
LGG 11	3	3.00	230	NGC 224	Sb		-21.69	-3.37	0	1.00	1885 A	I	0.01	160	
LGG 14	18	2.83	185	IC 43	SABc		-20.58	-0.72	-1.11	0.66	1973 U	II	0.58	178	
LGG 14	18	2.83	185	M+05-02-42	Sba		-20.36		-0.80	0.70	1954 ac?		0.78	216	
LGG 14	18	2.83	185	M+05-03-16	S		-20.67	-0.43	-0.67	0.67	1990 aa	Ic	0.63	83	
LGG 18	14	2.57	151	M+05-03-75	S		-20.85	-0.86	-0.48	0.15	1961 M		0.65	187	
LGG 21	5	3.40	89	NGC 488	Sb		-21.71	-1.21	0	0.92	1976 G		0.73	354	
LGG 26	21	2.76	182	NGC 536	SB		-22.06	-1.23	-0.07	0.09	1963 N	II	0.35	151	
LGG 32	3	2.67	144	IC1731	SABc		-19.90	-0.24	-0.59	1.00	1983 R	Ia	0.46	317	
LGG 37	18	2.44	191	NGC 735	Sb		-20.82	-0.93	-0.60	0.80	1972 L		0.69	81	
LGG 37	18	2.44	191	NGC 753	SABbc		-21.74	-0.36	-0.24	0.49	1954 E		0.82	28	
LGG 56	7	3.43	70	NGC 908	Sc		-21.26	-0.59	0	0.40	1994 ai	Ic	0.14	151	
LGG 57	3	3	87	UGC1867	Scd		-21.05		0	1.00	1989 ac?		0.70	112	
LGG 58	4	2.75	134	M+05-06-51	SABab		-20.29		-0.41	0.45	1965 K		0.55	18	
LGG 59	3	3.33	71	M-02-07-010	Sc		-18.57	-0.41	-0.09	0.22	1985 S	II	0.72	283	
LGG 61	7	2.71	100	IC1801	SBb		-19.67		-0.57	0.62	1976 H?		0.49	306	KPG68B
LGG 61	7	2.71	100	NGC 930	Sa		-20.94		-0.06	0.42	1992 bf	I	0.25	303	
LGG 63	6	3	125	NGC 977	SABa		-19.93		-0.58	0.52	1976 J	Ia	0.46	85	
LGG 65	3	3.00	62	M+06-06-62	SABd		-21.28	-0.94	0	0.62	1961 P	Ia	0.80	155	KPG72
LGG 66	12	2.83	153	M+05-07-29	Sc		-20.42	-0.54	-0.75	0.44	1982 V	I	0.27	239	
LGG 66	12	2.83	153	M+06-06-68	SBa		-20.65	0.09	-0.66	0.61	1938 A	I	0.83	164	
LGG 70	5	3.20	129	NGC1003	Scd		-19.42	-1.44	-0.40	0.90	1937 D	Ia	0.30	253	
LGG 71	13	3	91	NGC 991	SABc		-18.75	-0.80	-0.82	0.11	1984 L	Ib	0.48	254	
LGG 71	13	3	91	NGC1035	Sc		-19.22	-0.54	-0.63	0.13	1990 E	II	0.29	337	
LGG 71	13	3	91	NGC1084	Sc		-20.56	-0.20	-0.09	0.13	1963 P	Ia	0.36	120	
LGG 71	13	3	91	NGC1084	Sc		-20.56	-0.20	-0.09	0.13	1996 an	II	0.49	190	
LGG 73	5	3	85	NGC1073	SBc		-19.79	-1.12	-0.78	0.14	1962 L	Ic	0.53	34	
LGG 75	4	2.50	84	NGC1097	SBb	Sy1	-21.20	-0.31	0	0.22	1992 bd	II	0.04	357	
LGG 86	4	3	48	NGC1255	SABbc		-20.48	-0.80	0	0.74	1980 O	II	1.12	221	
LGG 88	11	2.09	159	NGC1275	CD	Sy2	-23.03	-0.71	0	0.40	1968 A	I	0.38	111	
LGG 94	15	2.80	106	NGC1310	SBcd		-19.02	-0.73	-1.23	0.98	1965 J		0.27	358	
LGG 94	15	2.80	106	NGC1316	SAB0	L	-22.11	-1.50	0	0.89	1980 N	Ia	0.71	25	RRPG75A
LGG 94	15	2.80	106	NGC1316	SAB0	L	-22.11	-1.50	0	0.89	1981 D	Ia	0.33	289	
LGG 94	15	2.80	106	NGC1350	SBab		-21.16	-1.55	-0.38	0.63	1959 A		0.52	355	
LGG 94	15	2.80	106	NGC1365	SBb	Sy1.8	-21.72	-0.06	-0.16	0.13	1957 C		0.47	231	
LGG 94	15	2.80	106	NGC1365	SBb	Sy1.8	-21.72	-0.06	-0.16	0.13	1983 V	Ic	0.24	313	
LGG 94	15	2.80	106	NGC1380	S0		-21.05	-1.46	-0.42	0.33	1992 A	Ia	0.46	315	
LGG 96	32	2.22	166	M-06-09-04	SBa		-17.56		-1.38	0.38	1969 A?		0.38		
LGG 97	24	2.58	146	NGC1332	S0		-20.24	-1.59	-0.38	0.77	1982 E		3.02	10	
LGG 97	24	2.58	146	NGC1325	Sbc		-20.07	-1.28	-0.45	0.89	1975 S	II	0.95	44	
LGG 102	3	2.67	99	NGC1411	S0		-18.21	-1.61	-0.82	0.27	1976 L	I	3.41	338	
LGG 102	3	2.67	99	NGC1448	Scd		-20.26	-0.61	0	1.00	1983 S	II	0.39	171	
LGG 107	3	3.33	5	NGC1511	Sa		-19.93	-0.06	0	0.47	1935 C		0.84	186	
LGG 111	6	2.50	113	NGC1532	SBb		-20.89	-1.04	0	0.56	1981 A	II	0.53	102	RRPG85A
LGG 118	6	2.83	141	NGC1667	SABc	Sy2	-21.75	-0.25	0	0.42	1986 N	Ia	0.31	351	
LGG 127	4	3.00	101	NGC1808	SABb	Sy2	-19.90	0.26	-0.27	0.19	1993 af	Ia	1.94	302	
LGG 145	6	2.83	135	NGC2268	SABbc		-21.20	-0.70	0	0.71	1982 B	Ia	0.29	38	
LGG 152	4	3.00	83	NGC2487	SBb		-21.32	-1.02	0	0.30	1975 O	Ia	0.44	257	KPG150B
LGG 154	5	2.60	96	NGC2441	SABb		-20.99	-0.90	-0.23	0.70	1995 E	Ia	0.38	294	
LGG 156	3	3.00	120	M+04-20-13	SBc		-20.55	-0.69	-0.16	0.08	1962 F		0.89	129	
LGG 156	3	3.00	120	NGC2565	SBbc		-20.95	-1.02	0	0.93	1960 M	I	0.66	317	
LGG 156	3	3.00	120	NGC2565	SBbc		-20.95	-1.02	0	0.93	1992 I	II	1.03	12	
LGG 165	5	3.00	66	NGC2715	SABc		-21.03	-1.34	-0.07	1.00	1987 M	Ic	0.14	257	
LGG 169	3	3.00	69	NGC2775	Sab		-20.56	-1.16	0	0.50	1993 Z	Ia	0.40	250	KIG309
LGG 176	5	3.20	70	NGC3031	I0		-21.56	-2.50	0	0.27	1993 J	IIb	0.21	255	KPG218A
LGG 182	9	3.11	44	M+01-25-25	SBd		-19.02		-0.38	0.75	1989 C	II p	0.07	246	
LGG 192	5	3.00	91	NGC3169	Sa	L	-20.47	-0.78	0	0.34	1984 E	II	0.68	71	KPG228A
LGG 193	4	3.25	134	NGC3147	Sbc	Sy2	-22.15	-0.65	0	0.60	1972 H	I	0.46	78	
LGG 193	4	3.25	134	NGC3147	Sbc	Sy2	-22.15	-0.65	0	0.60	1997 bq	Ia	0.61	338	
LGG 194	10	2.60	114	NGC3177	Sb		-18.69	0.01	-0.60	0.30	1947 A	II	1.04	296	
LGG 194	10	2.60	114	NGC3226	E2	L	-19.25		-0.37	0.73	1976 K	I	0.37	169	KPG234A
LGG 194	10	2.60	114	NGC3227	SABc	Sy1.5	-20.18	-0.72	0	0.75	1983 U	Ia	0.16	309	KPG234B
LGG 197	5	2.40	51	NGC3254	Sbc		-20.04	-1.63	0	0.86	1941 B		0.42	154	
LGG 207	5	3.00	63	UGC5695	S		-18.60		-0.59	1.00	1993 N	II n	0.65	143	
LGG 207	5	3.00	63	UGC5695	S		-18.60		-0.59	1.00	1994 N	II	0.72	98	
LGG 211	14	2.50	170	NGC3336	Sc		-21.16	-0.69	-0.14	0.75	1984 S		0.17	341	
LGG 214	4	3.00	39	NGC3389	Sc		-19.70		-0.21	1.00	1967 C	Ia	0.93	263	
LGG 216	4	2.75	48	NGC3367	SBc	Sy	-21.27	-0.44	0	1.00	1986 A	Ia	0.33	24	
LGG 216	4	2.75	48	NGC3367	SBc	Sy	-21.27	-0.44	0	1.00	1992 C	II	0.52	331	
LGG 219	5	3.20	72	NGC3370	Sc		-19.68	-0.74	0	1.00	1994 ae	Ia	0.48	175	
LGG 226	3	2.67	101	NGC3458	SAB		-19.41		-0.17	1.00	1991 F	Ia	0.58	146	
LGG 231	4	3.00	99	NGC3627	SABb	Sy2	-21.12	-0.73	-0.01	0.41	1973 R	II	0.24	316	
LGG 231	4	3.00	99	NGC3627	SABb	Sy2	-21.12	-0.73	-0.01	0.41	1989 B	Ia	0.20	270	
LGG 231	4	3.00	99	NGC3627	SABb	Sy2	-21.12	-0.73	-0.01	0.41	1997bs	IIn	0.29	60	
LGG 232	4	2.50	57	NGC3625	SABb		-19.47	-1.30	-0.57	0.17	1983 W	Ia	0.40	21	
LGG 241	8	3.00	154	NGC3631	Sc		-20.75	-0.88	0	1.00	1964 A	V	0.78	156	
LGG 241	8	3.00	154	NGC3631	Sc		-20.75	-0.88	0	1.00	1965 L	II	0.46	138	
LGG 241	8	3.00	154	NGC3631	Sc		-20.75	-0.88	0	1.00	1996 bu	II n	0.80	120	
LGG 241	8	3.00	154	NGC3913	Sd		-18.04	-1.19	-1.08	0.49	1963 J	Ia	0.17	42	
LGG 241	8	3.00	154	NGC3913	Sd		-18.04	-1.19	-1.08	0.49	1979 B	Ia	0.57	227	
LGG 247	3	3.00	8	NGC3780	Sc		-20.95	-0.87	0	1.00	1978 H	II	0.23	298	
LGG 247	3	3.00	8	NGC3780	Sc		-20.95	-0.87	0	1.00	1992 bt	II	0.24	159	
LGG 250	7	3.00	125	NGC3733	SABcd		-19.32	-1.69	-0.40	0.73	1980 D	II	0.84	118	
LGG 250	7	3.00	125	NGC3756	SABbc		-20.16	-1.22	-0.07	0.66	1975 T	II	0.92	243	
LGG 255	5	2.00	96	NGC3904	E2-3		-19.87		-0.47	0.37	1971 C	Ia	2.18	239	
LGG 258	27	2.89	118	NGC3992	SBbc		-21.12	-1.63	0	0.64	1956 A	Ia	0.35	246	
LGG 258	27	2.89	118	NGC4088	SABbc		-20.35	-0.70	-0.31	0.50	1991 G	II	0.50	31	
LGG 258	27	2.89	118	NGC4157	SABb		-19.83	-0.62	-0.51	0.70	1937 A	II	0.59	238	
LGG 258	27	2.89	118	NGC4157	SABb		-19.83	-0.62	-0.51	0.70	1955 A		0.56	214	
LGG 258	27	2.89	118	NGC4220	S0		-19.01	-0.99	-0.84	0.87	1983 O		0.24	125	
LGG 258	27	2.89	118	UGC6983	SBcd		-18.60	-1.40	-1.01	0.56	1994 P	II	1.07	262	
LGG 258	27	2.89	118	UGC6983	SBcd		-18.60	-1.40	-1.01	0.56	1964 E	Ia	0.92	93	
LGG 259	6	3.00	82	IC2973	SBd		-19.43		-0.89	1.00	1991 A	Ic	0.77	276	
LGG 259	6	3.00	82	NGC3995	Sm		-21.66		0	0.45	1988 ac		0.73	43	
LGG 263	12	2.58	72	NGC4038	SBm		-21.36		0	0.39	1974 E		0.65	143	RRPG206A
LGG 263	12	2.58	72	NGC4039	Sm		-21.12		-0.10	0.39	1921 A		0.32	148	RRPG206B
LGG 266	3	2.67	85	NGC4041	Sbc		-19.94	-0.31	-0.20	0.23	1994 W	II n	0.24	296	
LGG 269	16	2.75	118	NGC3938	Sc		-19.95	-0.93	0	0.77	1961 U	II L	0.81	352	
LGG 269	16	2.75	118	NGC3938	Sc		-19.95	-0.93	0	0.77	1964 L	Ic	0.19	36	
LGG 269	16	2.75	118	NGC4051	SABbc	Sy1.5	-19.84	-0.94	-0.04	0.72	1983 I	Ic	0.38	215	
LGG 269	16	2.75	118	NGC4096	SABc		-19.84	-1.26	-0.04	0.75	1960 H	Ia	0.78	146	
LGG 269	16	2.75	118	NGC4183	Scd		-19.72		-0.09	0.64	1968 U?		0.63	1	
LGG 276	8	2.75	73	NGC4185	Sbc		-20.63	-0.85	-0.05	0.33	1982 C	Ia	0.72	36	
LGG 279	11	2.73	186	NGC4136	SABc		-18.41	-1.25	-0.69	1.00	1941 C	II	0.67	305	

Table 3 – *continued*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
LGG 279	11	2.73	186	NGC4414	Sc		-19.98	-0.50	-0.06	0.89	1974 G	Ia	0.57	148	
LGG 281	18	2.67	132	NGC4273	SBc		-20.78	-0.24	-0.03	0.04	1936 A	II	0.42	13	
LGG 285	25	2.68	134	NGC4189	SABcd		-20.33	-0.60	-1.03	0.58	1966 E	II	0.77	109	
LGG 285	25	2.68	134	NGC4254	Sc		-22.52	-0.44	-0.16	0.41	1967 H		0.51	295	
LGG 285	25	2.68	134	NGC4254	Sc		-22.52	-0.44	-0.16	0.41	1972 Q	II P	0.60	30	
LGG 285	25	2.68	134	NGC4254	Sc		-22.52	-0.44	-0.16	0.41	1986 I	II P	0.24	285	
LGG 285	25	2.68	134	NGC4568	Sc		-21.61		-0.52	0.76	1990 B	Ib/c	0.16	270	KPG347B
LGG 287	16	2.69	183	NGC4303	SABbc	Sy	-21.75	-0.55	0	0.50	1926 A	II	0.36	67	
LGG 287	16	2.69	183	NGC4303	SABbc	Sy	-21.75	-0.55	0	0.50	1961 I	II	0.42	320	
LGG 287	16	2.69	183	NGC4303	SABbc	Sy	-21.75	-0.55	0	0.50	1964 F	II	0.14	150	
LGG 287	16	2.69	183	NGC4496A	SBm		-20.20		-0.62	0.24	1960 F	Ia	0.38	246	KPG343A
LGG 287	16	2.69	183	NGC4527	SABbc	L	-21.35	-0.31	-0.16	0.43	1915 A		0.43	144	
LGG 287	16	2.69	183	NGC4527	SABbc	L	-21.35	-0.31	-0.16	0.43	1991 T	Ia	0.54	214	
LGG 287	16	2.69	183	NGC4536	SABbc		-21.65	-0.41	-0.04	0.51	1981 B	Ia	0.60	189	
LGG 289	63	2.68	217	NGC4302	Sc		-20.02		-0.81	0.17	1986 E	II	0.82	147	KPG332B
LGG 289	63	2.68	217	NGC4321	SABbc	L	-22.05	-0.75	0	0.08	1901 B	I	0.56	192	
LGG 289	63	2.68	217	NGC4321	SABbc	L	-22.05	-0.75	0	0.08	1914 A		0.55	296	
LGG 289	63	2.68	217	NGC4321	SABbc	L	-22.05	-0.75	0	0.08	1959 E	I	0.32	354	
LGG 289	63	2.68	217	NGC4321	SABbc	L	-22.05	-0.75	0	0.08	1979 C	II	0.53	317	
LGG 289	63	2.68	217	NGC4411B	SABcd		-18.50	-1.09	-1.42	0.66	1992 ad	II	0.58	46	KPG336B
LGG 289	63	2.68	217	NGC4486	E	Sy	-21.96	-2.61	-0.04	0.34	1919 A	I	0.40	201	
LGG 289	63	2.68	217	NGC4564	E6		-19.29		-1.10	0.46	1961 H	Ia	0.05	204	
LGG 289	63	2.68	217	NGC4579	SABb	Sy1.9	-21.49	-1.10	-1.10	0.45	1988 A	II P	0.33	29	
LGG 289	63	2.68	217	NGC4579	SABb	Sy1.9	-21.49	-1.10	-1.10	0.45	1989 M	Ia	0.28	272	
LGG 289	63	2.68	217	NGC4639	SABbc	Sy1.8	-19.07	-1.05	-1.19	0.44	1990 N	Ia	0.87	143	
LGG 289	63	2.68	217	NGC4647	SABc		-19.93	-0.55	-0.85	0.54	1979 A	I	0.68	280	KPG353A
LGG 290	17	3.41	142	NGC4258	SABbc	Sy1.9	-21.13		0	0.85	1981 K	II	0.26	150	
LGG 290	17	3.41	142	NGC4490	SBd		-20.67	-0.83	-0.19	0.23	1982 F	II P	0.22	237	KPG341B
LGG 290	17	3.41	142	NGC4618	SBm		-19.04	-1.17	-0.84	0.31	1985 F	Ib	0.13	242	KPG349A
LGG 291	6	3.33	169	NGC4214	IABm		-17.18		-1.90	0.85	1954 A	Ib	0.92	257	
LGG 292	59	2.42	152	NGC4340	SB0		-18.74		-1.09	0.22	1977 A		0.51	110	
LGG 292	59	2.42	152	NGC4374	E1		-20.72	-2.32	-0.30	0.46	1957 B	Ia	0.25	161	
LGG 292	59	2.42	152	NGC4374	E1		-20.72	-2.32	-0.30	0.46	1991 bg	Ia	0.30	334	
LGG 292	59	2.42	152	NGC4374	E1		-20.72	-2.32	-0.30	0.46	1980 I	Ia	2.35	64	
LGG 292	59	2.42	152	NGC4382	S0		-20.43		-0.42	0.21	1960 R	Ia	0.63	238	KPG334A
LGG 292	59	2.42	152	NGC4636	E/S0	L	-20.74		-0.29	0.46	1939 A	Ia	0.18	20	
LGG 292	59	2.42	152	NGC4688	SBcd		-17.79	-0.82	-1.47	0.66	1966 B	II	0.47	115	
LGG 292	59	2.42	152	NGC4772	Sa	L	-19.23		-0.89	0.62	1988 E		0.270	303	
LGG 295	4	2.50	130	NGC4512	SBdm		-18.99	-0.99	-0.65	0.16	1995 J	II	0.79	51	KPG345A
LGG 295	4	2.50	130	NGC4545	SBcd		-20.61	-0.99	0	1.00	1940 D		0.36	246	
LGG 298	54	2.48	248	NGC4650A	S		-19.51	-0.84	-0.94	0.07	1990 I	I b	1.42	136	
LGG 299	3	3.00	100	NGC4632	Sc		-20.59	-0.79	-0.05	1.00	1946 B	II	0.19	23	
LGG 299	3	3.00	100	NGC4666	SABc	L	-20.71	-0.09	0	0.40	1965 H	II P	0.28	45	
LGG 307	14	3.07	188	NGC4699	SABb	Sy	-21.22	-1.02	0	0.95	1948 A		0.50	175	
LGG 307	14	3.07	188	NGC4699	SABb	Sy	-21.22	-1.02	0	0.95	1983 K	II P	1.75	126	
LGG 314	18	3.11	160	NGC4948	SBdm		-18.37		-1.01	0.86	1994 U	Ia	0.780		
LGG 315	12	3.08	215	NGC4753	I0		-20.50	-1.18	0	0.32	1965 I	Ia	0.66	232	
LGG 315	12	3.08	215	NGC4753	I0		-20.50	-1.18	0	0.32	1983 G	Ia	0.12	306	
LGG 316	3	1.67	137	NGC4783	E		-21.86		0	1.00	1956 B		0.78	152	
LGG 321	3	3.00	48	NGC4902	SBb		-21.26	-0.73	0	1.00	1979 E?		0.76	189	
LGG 321	3	3.00	48	NGC4902	SBb		-21.26	-0.73	0	1.00	1991 X	Ia	0.20	135	
LGG 333	5	3.00	112	NGC4981	SABbc	L	-19.82	-0.52	-0.24	0.57	1968 I	Ia	0.09	312	
LGG 334	9	3.22	110	NGC5033	Sc	Sy1.9	-20.96	-0.94	0	0.36	1950 C		1.44	229	
LGG 334	9	3.22	110	NGC5033	Sc	Sy1.9	-20.96	-0.94	0	0.36	1985 L	II	0.44	23	
LGG 335	3	3.00	26	NGC5020	SABbc		-21.15	-0.39	0	1.00	1991 J	II	0.77	119	
LGG 339	17	2.29	199	E323-G99	SABc		-20.27	-0.49	-0.50	0.34	1984 I	Ib	0.72	0	
LGG 339	17	2.29	199	NGC5090	E2		-21.17		-0.14	0.83	1981 C?		0.29	104	RRPG242A
LGG 342	8	2.75	125	E269-G57	SABb		-21.40		-0.01	0.96	1992 K	Ia P	0.19	242	
LGG 344	7	3.14	108	NGC5128	S0	Sy2				0.41	1986 G	Ia	0.22	35	
LGG 347	4	3.25	135	NGC5055	Sbc	L	-21.15	-1.14	0	0.75	1971 I	Ia	0.68	182	
LGG 347	4	3.25	135	NGC5194	Sbc	Sy2	-20.50	-0.87	-0.26	0.87	1994 I	Ic	0.07	74	KPG379A
LGG 348	3	2.00	74	NGC5082	SB0		-20.43		0	0.79	1958 F?		0.80	173	
LGG 350	5	2.60	182	NGC5127	E		-21.08		0	0.24	1991 bi	Ia	0.17	193	
LGG 355	3	3.67	106	NGC5236	SABc		-22.25	-0.88	-0.13	1.00	1923 A	II	0.32	55	
LGG 355	3	3.67	106	NGC5236	SABc		-22.25	-0.88	-0.13	1.00	1945 B		0.52	268	
LGG 355	3	3.67	106	NGC5236	SABc		-22.25	-0.88	-0.13	1.00	1950 B		0.27	207	
LGG 355	3	3.67	106	NGC5236	SABc		-22.25	-0.88	-0.13	1.00	1957 D		0.33	108	
LGG 355	3	3.67	106	NGC5236	SABc		-22.25	-0.88	-0.13	1.00	1968 L	II	0.01	207	
LGG 355	3	3.67	106	NGC5236	SABc		-22.25	-0.88	-0.13	1.00	1983 N	Ib	0.42	254	
LGG 361	13	2.92	122	NGC5371	SABbc	L	-21.88	-0.91	0	0.62	1994 Y	II n	0.29	350	
LGG 364	3	2.67	127	NGC5378	SBa		-19.51		-0.29	0.46	1991 ak	Ia	0.50	30	
LGG 371	3	3.00	40	NGC5457	SABcd		-20.87	-0.49	0	0.51	1909 A	II	0.87	167	KIG610
LGG 371	3	3.00	40	NGC5457	SABcd		-20.87	-0.49	0	0.51	1951 H	II	0.41	27	
LGG 371	3	3.00	40	NGC5457	SABcd		-20.87	-0.49	0	0.51	1970 G	II L	0.45	151	
LGG 372	6	2.67	82	NGC5480	Sc		-19.94	-0.52	-0.34	0.49	1988 L	Ib	0.28	343	KPG416A
LGG 373	6	2.50	123	NGC5485	S0		-19.66		-0.20	0.36	1982 W	Ia	0.93	273	
LGG 374	4	2.75	108	NGC5493	S0		-20.68		-0.20	1.00	1990 M	Ia	0.33	9	
LGG 374	4	2.75	108	NGC5426	Sc		-20.57		-0.24	0.57	1991 B	Ia	0.27	273	
LGG 374	4	2.75	108	NGC5427	Sc	Sy2	-21.17	-0.49	0	0.55	1976 D	Ia	0.65	71	
LGG 381	3	3.00	44	NGC5548	S0/a	Sy1.5	-21.55	-0.90	0	0.71	1984 Z?	II	0.03		
LGG 382	3	2.67	66	M+02-37-15a	SBb		-19.97	-0.68	-0.30	1.00	1988 F	Ia	0.97	238	
LGG 386	22	2.95	114	NGC5668	Sd		-19.88	-0.81	-0.79	0.58	1952 G		0.32	175	
LGG 386	22	2.95	114	NGC5668	Sd		-19.88	-0.81	-0.79	0.58	1954 B	Ia	0.20	207	
LGG 386	22	2.95	114	NGC5746	SABb		-21.86	-1.53	0	0.41	1983 P	Ia	0.15	131	KPG434B
LGG 390	3	2.33	67	M-03-38-25	SABbc		-19.96	-0.79	-0.69	1.00	1994 V		0.49	273	
LGG 393	8	1.88	147	NGC5854	SB0		-19.52		-0.69	0.49	1980 P	I	0.16		
LGG 394	3	3.00	134	NGC5857	SBb		-20.96		-0.40	0.48	1950 H		0.76	107	KPG455A
LGG 394	3	3.00	134	NGC5857	SBb		-20.96		-0.40	0.48	1955 M		1.03	308	
LGG 395	4	3.00	111	NGC5905	SBb	Sy1	-21.05	-0.58	-0.14	0.76	1963 O	I	0.61	40	
LGG 396	3	2.67	59	NGC5879	Sbc	L	-19.40	-1.10	-0.68	0.53	1954 C	II	0.36	139	
LGG 396	3	2.67	59	NGC5907	Sc		-21.11	-1.37	0	1.00	1940 A	II L	0.92	112	
LGG 422	22	2.36	182	IC4798	S0		-21.36		-0.40	0.60	1971 R		0.24	71	
LGG 427	12	2.50	184	IC4831	SABb		-22.15	-1.40	0	0.33	1992 N	II	1.02	44	
LGG 429	8	2.63	115	IC4963	Sba		-20.27	0.00	-0.79	0.82	1987 I	Ia	0.14	256	
LGG 436	3	3.00	48	NGC6907	SBbc		-21.91	-0.31	0	1.00	1984 V?		0.56	110	
LGG 439	4	3.00	87	UGC11616	Scd					0.96	1991 au	II	0.47	98	
LGG 441	11	2.27	133	NGC7038	Sc		-22.32	-0.88	0	0.84	1983 L	Ia	0.38	151	
LGG 459	4	3.00	24	NGC7331	Sb	L	-21.40	-0.93	0	0.45	1959 D	II L	0.27	84	
LGG 465	3	2.67	60	NGC7418A	Sd		-18.31	-0.64	-0.97	0.74	1983 M?		0.96	98	
LGG 466	5	2.67	80	IC5270	SBc		-19.99	-0.70	-0.30	0.35	1993 L	Ia	0.53	69	
LGG 469	5	2.00	99	NGC7448	Sbc		-21.18	-0.58	0	0.75	1980 L		0.34	206	
LGG 469	5	2.00	99	NGC7448	Sbc		-21.18	-0.58	0	0.75	1997 dt	Ia	0.18	209	
LGG 473	15	2.20	170	NGC7619	E		-21.82		0	0.16	1970 J	Ia	0.34	132	
LGG 473	15	2.20	170	NGC7634	SB0		-19.97		-0.74	0.21	1972 J	Ia	1.12	157	
LGG 476	4	2.75	37	IC1501	SABbc		-20.35	-0.61	0	0.51	1993 ad	II	0.65	98	
LGG 478	3	3.33	31	NGC7713	SBd		-18.41		-0.05	0.48	1982 L	II	0.65	84	
LGG 480	5	3.00	98	NGC7723	SBb		-20.55	-0.70	-0.067	0.59	1975 N	Ia	0.56	200	

Table 4. Mean parameters (and standard deviation) of the SNe host galaxies

	KIG hosts		KPG+RRPG hosts		LGG hosts	
	Ia	II+Ib/c	Ia	II+Ib/c	Ia	II+Ib/c
$< M_B >$	-20.56 ± 0.20	-20.36 ± 0.86	-21.41 ± 0.74	-20.57 ± 0.98	-20.50 ± 0.98	-20.44 ± 1.13
$< T >$	1.9 ± 3.3	4.7 ± 2.0	1.7 ± 2.6	5.0 ± 1.4	1.9 ± 3.5	4.1 ± 1.4

of the geometrical center in the groups were compared with the distributions on the opposite sides. Again no differences were found at 95% significance level.

We investigated also the locations and properties of the host galaxies of SNe inside the groups. The radial distribution of SN parent galaxies with respect to the geometrical centers of the groups (R_P/R_{GR}) does not differ from the radial distribution of all other members of the groups. The distributions of the number of galaxies in the groups and the mean morphological class of the groups hosting SNe was compared with the distributions of all Garcia (1993) groups. Once more the distributions were similar and independent on SN type. We have therefore evidence that the mean properties of the groups hosting SNe are not different from others.

The fact that groups with multiple SNe are richer and have in average later morphological types, is consistent with the well known dependence of the SN production on galaxy type and luminosity.

3.3 The frequency of SNe in isolated galaxies, in isolated pairs and groups of galaxies

According to the Tables 1, 2 and 3 the ratios of SN types, $n_{Ia}/n_{(II+Ib/c)}$, in isolated parents, in members of pairs and groups of galaxies are equal to 0.29, 0.54, 0.78 respectively. Taken to face value this suggests a decrease of the massive progenitors population moving to denser environments. It is well known however that not all galaxies in the sky are equally surveyed for the detection of SNe and that selection effects play a crucial role in the SN discovery (e.g. Cappellaro et al. 1993a). Therefore, the numbers above should not be taken as representative of the intrinsic rate of explosions of the different SN types.

We have used the combined archives of five SN searches, namely the Asiago, Crimea, Calan-Tololo and OCA photographic surveys and the visual search by Evans, and computed SNe rates in the three samples following the prescriptions by Cappellaro et al. (1999). This computation makes use of the control time method which has been introduced by Zwicky (1942) and revisited by several authors (Cappellaro & Turatto 1988, van den Bergh, McClure & Evans 1987, van den Bergh & McClure 1994, Cappellaro et al. 1993, 1997, 1999).

254 isolated galaxies from KIG, 558 galaxies in pairs from KPG and RRPG, and 2596 galaxies from Garcia (1993) groups were surveilled in at least one of the afore mentioned SN searches. During the surveillance only two SNe were found in the sample of isolated galaxies, the type Ia SN 1993C and the type II SN 1969B. 17 were found in pairs, while 73 are the SNe detected by the searches in groups of galaxies.

The rates of SNe for each of the three samples are reported in Table 5. The rates per unit of blue luminosity are expressed in SNu, where $1SNu = 1SN(100yr)^{-1}(10^{10}L_{\odot}^{B})$. The numbers of SNe in each cell of Table 5 are reported in brackets. Following Cappellaro et al. (1997), unclassified SNe were distributed among the three basic types according to the observed distribution in the given sample. In the last column 5 are the average rates after Cappellaro et al. (1999). Because the same method has been used, these numbers are directly comparable. The indicated standard errors take into account the event statistics, the uncertainty on the input parameters and the bias corrections. The rates for the isolated galaxies are only nominal values (and no error is reported) since they are based on a single object per each SN type.

It results that the rate of SNe in pairs is systematically higher than in groups (by $\sim 60\%$) and in the average sample (by $\sim 40\%$) though, because of the relatively large uncertainties, this is not a solid conclusion. This is consistent with the similar finding of Smirnov and Tsvetkov (1981) which however did not account for the differences in surveillance time of the different galaxy samples.

As mentioned above, the fact that SNe are more frequent in the brighter components of the pairs and groups is consistent with the fact that in all galaxy types the SNe rate are proportional to the galaxy luminosity (e.g. Cappellaro et al. 1993a).

3.4 Multivariate Factor Analysis

As a further, general exploration we applied the Multivariate Factor Analysis (MFA) method to our samples. The MFA is a statistical method for detection of correlation among a set of m initial variables measured on n objects through a reduced number ($p < m$) of linearly independent factors $F1, F2 ... Fp$. The final aim of MFA is to reduce the number of independent variables (factors) required to account for the variance of a class of objects. This method has been used in astronomy by several authors (e.g. Whitemore 1984; Vader 1986; Patat et al. 1994; Petrosian & Turatto 1992, 1995). A detailed description of MFA method can be found in Harman (1967) and Afifi & Azen (1979).

The initial variables used for the isolated parent galaxies of SNe were the morphological type - T, the absolute magnitude of the SN parents - M_B, the inclination of parent galaxy - INC, a dummy parameter - AGN for the nuclear activity (dAGN=0 for normal and 1 for active nuclei), the logarithmic ratio - LogL_{FIR}/L_B, a dummy parameter - SN, for the SN type (dSN=1 for SNIa, 2 for core-collapse SNe, 1.5 for unclassified SNe) and the deprojected relative distances of SNe from the centers of parent galaxies - R_0/R_{25}.

The accumulated dispersion carried by the first three factors is about 66%. Adopting a correlation threshold of 0.7 we find that the first factor, $F1$, correlates the morpho-

Table 5. Frequency per luminosity unit (SNu^*) with standard errors

SN type	Isolated galaxies	Galaxies in pairs	Galaxies in groups	Cappellaro et al. (1999)
Ia	0.14 (1)	0.29 ± 0.11 (8.7)	0.22 ± 0.06 (42.2)	0.20 ± 0.06(69.6)
II+Ib/c	0.28 (1)	0.66 ± 0.31(8.3)	0.37 ± 0.17 (30.8)	0.48 ± 0.19 (67.4)
ALL	0.42 (2)	0.95 ± 0.32 (15)	0.59 ± 0.18(73)	0.68 ± 0.20(137)

$*1SNu = 1SN(100yr)^{-1}(10^{10}L_{\odot}^{B}); H_0 = 75kms^{-1}Mpc^{-1}$

logical type of SN host galaxies with the logarithmic ratio LogL_{FIR}/L_B, with early type galaxies having smaller IR excess, a well known finding for all galaxies. Factor two, $F2$, correlates the relative distance R_0/R_{25} of SNe and the absolute blue magnitude of the host galaxies with brighter galaxies hosting the more distant SNe from the nucleus. This is most likely a selection effect of SN searches. In magnitude limited samples, more distant galaxies are on average intrinsically brighter than nearby galaxies; at the same time, because of the Shaw effect, SNe in distant galaxies are discovered at higher distance from the nucleus (e.g. Cappellaro & Turatto 1997). The third factor, $F3$, accounts mainly for the SN type.

According to the theory of MFA the factors are orthogonal, hence the corresponding initial variables are independent. It means that for the isolated galaxy sample there is no relation between SN type, their radial distribution and the parameters of the host galaxy, in particular their FIR luminosity excess, which is thought to characterize their star formation activity.

If we exclude from the analysis the galaxy inclination, thus extending the sample also to non-disk dominated galaxies, only two factors have eigenvalues larger than 1. The first factor, $F1$, correlates the nuclear activity type of SN host galaxies with the LogL_{FIR}/L_B with also a significant contribution from the morphological type. The second and third factors remain unaffected.

A similar factor analysis was conducted for isolated pairs using the same parameters described above, plus the logarithmic ratio of the blue luminosity of SN parent to that of the neighbor galaxy - LogL_P/L_N, the radial velocity differences - ΔV, the ratio of the projected distance of SN from the center of parent galaxy to the projected distance between the two members of the systems - $R_{SN}/R_{1,2}$, and the dummy variable - PA, indicating the location of SNe with respect to the companion (0 when the SN is on the companion side, 1 otherwise).

The accumulated dispersion carried by the first four factors is about 68%. With the correlation threshold of 0.7 the first factor, $F1$, is the combination of morphology, activity class and logL_{FIR}/L_B , and can be understood considering that early type galaxies host more frequently AGN and have smaller infrared excess than late type galaxies. $F2$ accounts mainly for $R_0/R_{1,2}$. $F3$ indicates a correlation between absolute blue magnitude and LogL_P/L_N, which results from the well known properties that SN rate per unit galaxy luminosity is a costant. $F4$ accounts mainly for ΔV.

For the sample of SNe in groups we have added two variables characterizing the groups, i.e. the number galaxies in the group - NUMGAL, the standard deviation of the heliocentric radial velocities of the group members - SIGMA, and two variables characterizing the SN host galaxy in the context of the group, i.e the logarithmic ratio of its blue luminosity to that of the most luminous galaxy of the group - LogL_P/L_{LG}, and the distance of the host galaxy from geometrical center of the group relative to that of the most distant member of group - R_P/R_{GR}. In this analysis the dummy variable PA represents the SN location in the direction -1, or in the opposite direction - 0, of the geometrical center of the group.

The accumulated dispersion for the first four factors is rather low, 60%. F1 combines two parameters of the group NUMGAL and SIGMA, with richer groups having higher velocity dispersion. $F2$ correlates the absolute magnitudes of SNe parents, M_B, and LogL_P/L_{LG}, due to the presence in both variables of the galaxy luminosity. $F3$ accounts mostly for the morphological type of SNe hosts. No clear correlation appears from $F4$.

Removing the galaxy inclination, i.e. considering all galaxy types, the first three factors remain unchanged while $F4$ accounts only for PA.

Initial variables of orthogonal factors are independent, which means that in groups of galaxies there is no relation between type, location and distribution of SNe, total star formation activity in galaxies of a given type and the parameters of the groups.

A more general exploratory analysis has been performed by merging the three samples, considering the variables in common plus a dummy parameter describing the multiplicity of the parent system (1 for isolated, 2 for pairs and 3 for groups of galaxies). Three first factors loadings accumulated about 55% of the dispersion. $F1$, is the morphological type of the SN host galaxies. $F2$ correlates absolute blue luminosity of SNe hosts with AGN class of galaxies. $F3$ is related to the dummy parameter describing different systems. It means that there is no correlation among the parameters characterizing SNe, their host galaxies and different systems of galaxies.

4 CONCLUSIONS

In order to investigate the influence of the environment on the star formation we have used as indicators the SNe exploded in isolated galaxies, in pairs and in groups of galaxies. Indeed, core collapse SNe which descend from massive, short-lived progenitors, explode only few millions years after the births of the progenitors and can be considered as probes of recent star formation activity (Cappellaro et al. 1999).

The samples, described in Sect. 2, were sufficiently large to derive SN rates, radial distributions inside the parent galaxies, and for SNe in multiple systems, also the locations inside the systems.

The mean morphological types and luminosities of the SN host galaxies in different systems are similar. Contrary to the case of core collapse SNe, the average absolute magnitudes of parent galaxies of SNIa is brighter in paired galaxies than in other systems. Currently, we have no interpretation for this finding.

We found that the rate of SNe in galaxies member of pairs is $\sim$40% higher than in the average galaxy and $\sim$ 60 higher than in galaxies member of groups. Although, due to the large uncertainties this is not a solid conclusion, we can speculate that the higher SN rate is consistent with the enhanced star formation rate in close interacting system and instead more mild interaction, as that occuring in groups, does not affect significantly the SF rate. We remark that since only a fraction of the galaxy pairs experience strong interaction, the effect on the complete sample is expected to be diluted.

Also the radial distributions of core-collapse SNe do not differ in various systems and are comparable to the radial distributions founds by Bartunov et al. (1992) on a general sample. The azimuthal distributions of SNe inside their parent galaxies in relation to the location of the neighbors in pairs and groups of galaxies does not reveal any effect. It must be noted that, because of observational limitations, our investigation does not probe the SN frequencies and distributions in the circumnuclear regions of the galaxies.

An extensive Multivariate Factor Analysis has been performed including parameters of the SNe, physical and geometrical parameters of the parent galaxies and of the environment. A number of known and/or obvious correlations have been pointed out. Anyway, no clear correlation has been revealed between the environment of the host galaxies and the hosted SNe.

We conclude, therefore, that there is no clear effect of the galaxy environment on the SN production, with the possible exception of strongly interacting systems, and that the properties of the host galaxies are the same in field and in denser surroundings.

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